# Cautand originea masei
# (Cautand bosonul Higgs)


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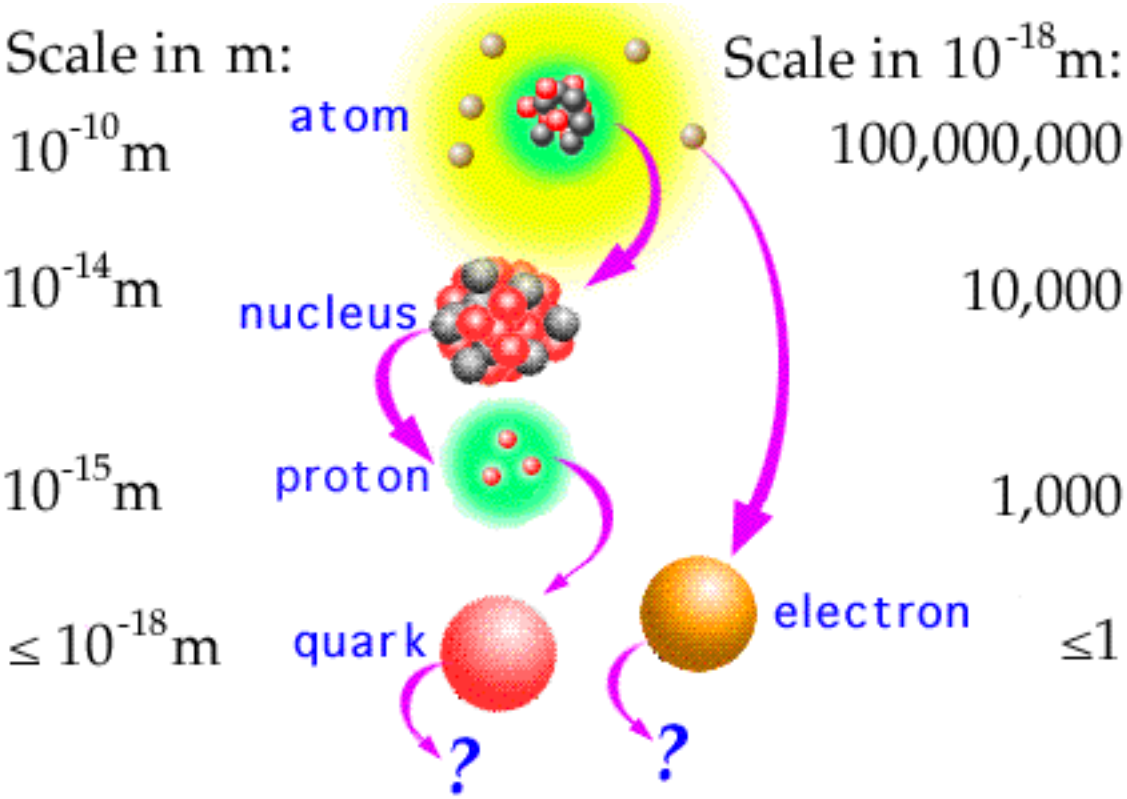
"Quarks. Neutrinos. Mesons. All those damn particles you can't see. That's what drove me to drink. But now I can see them!"

# De la mare la mic …



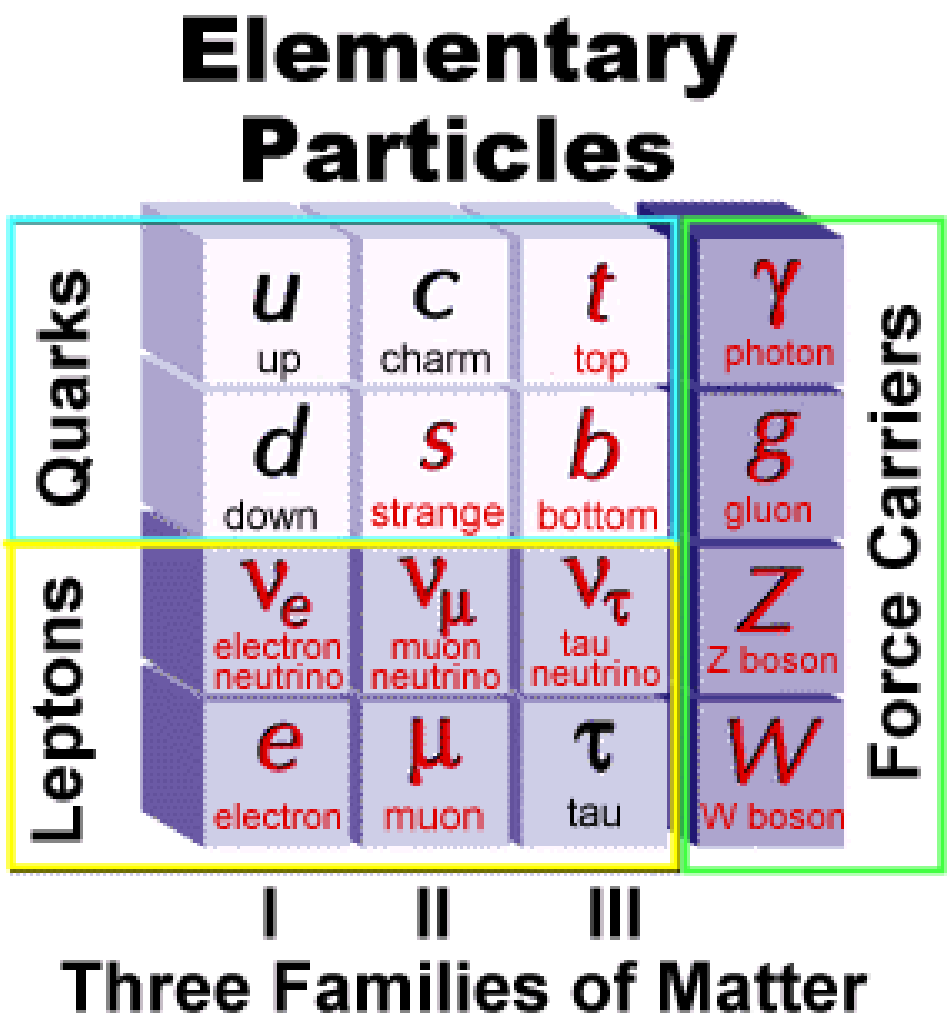
# Universul ca o prajitura


**Tava: spatiu-timp**

**Ingrediente: ~ 20 particule elementare**

**Reteta: 4 forte (interactii) elementare**

# Particule si forte elementare




**Forta electromagnetica**

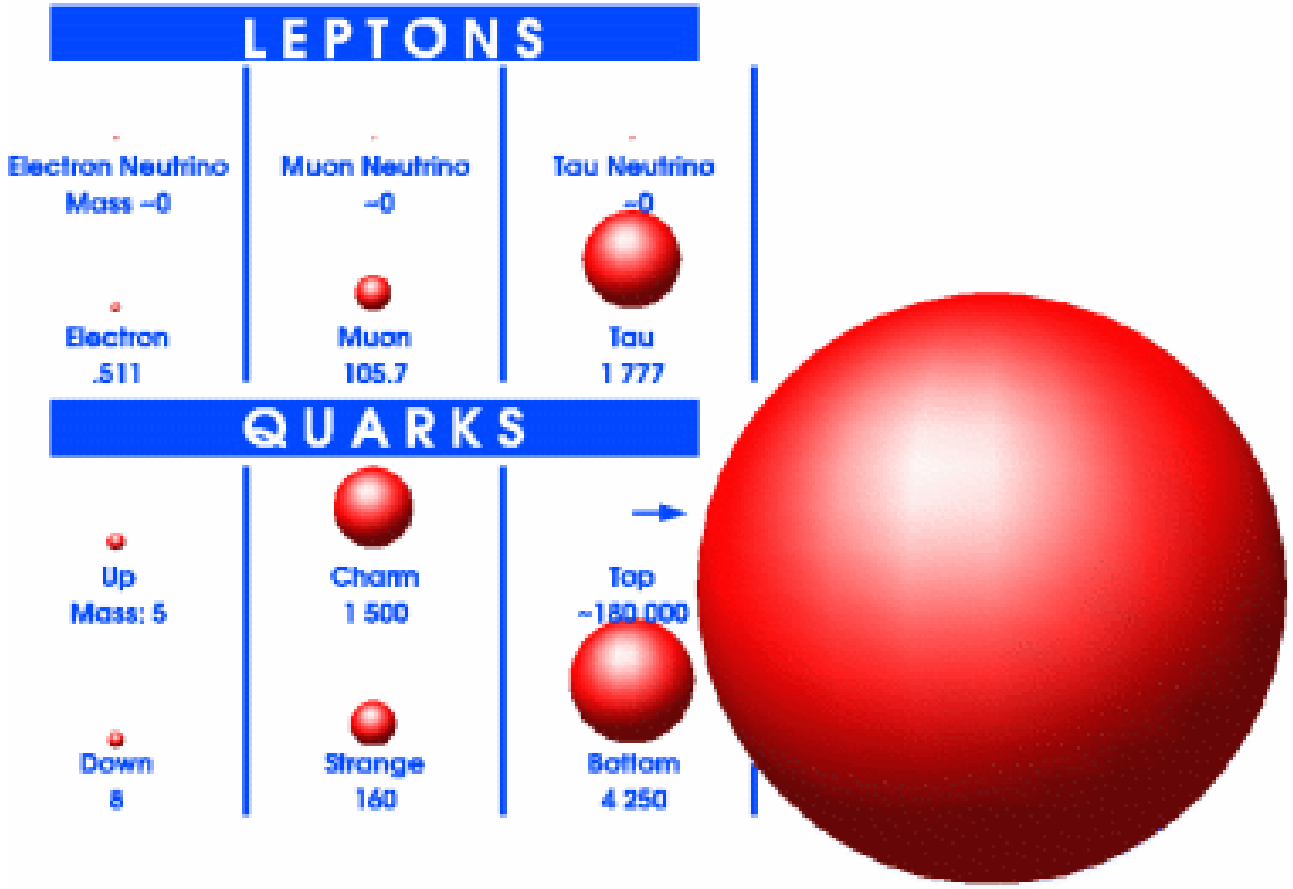
**Forta tare**

**Forta slaba**

**Forta slaba**

# O mare varietate de mase

**Masa reprezentata de suprafata**



# Masa particulelor elementare

## Leptoni Cuarci Purtatori de forta

## Unele masive cat atomi masivi!

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| | | | | | | | | | | | | | | | |
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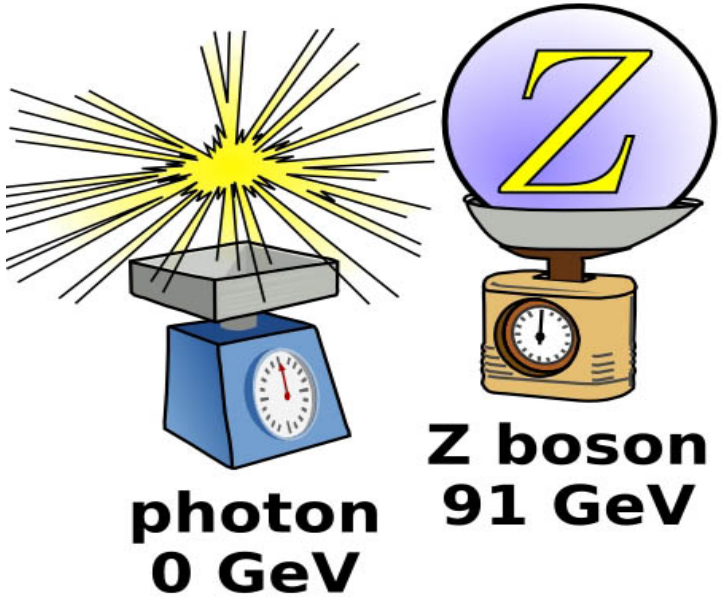
# Fotonul si bosonul Z



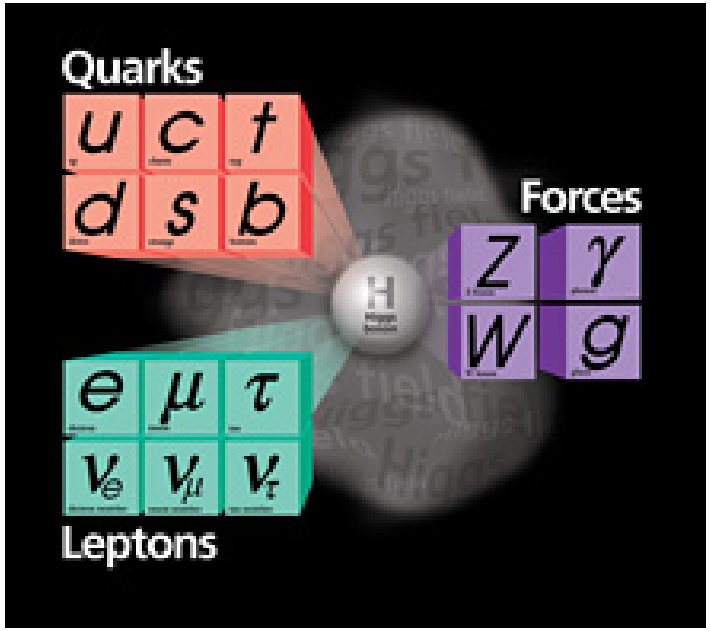

**Forta electroslaba = forta electromagnetica + forta slaba**

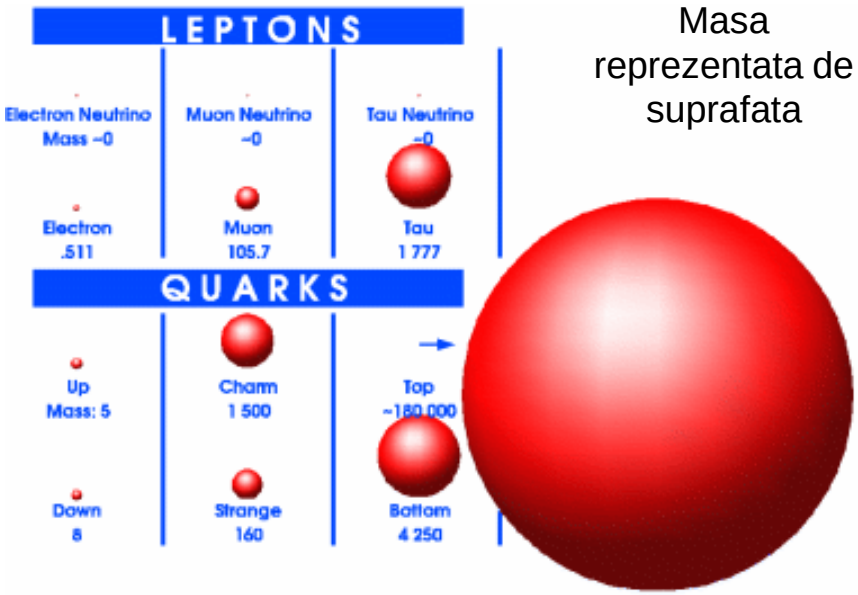
**Fotonul == Bosonul Z**

**Apoi, spontan, simetria este rupta!**

**Fotonul != Bosonul Z**
**Fotonul ramane fara masa; Bosonul Z primeste masa.**

# Ingredientul lipsa, bosonul Higgs




Masa reprezentata de suprafata

**Care este originea masei particulelor elementare?**

**Teoria propune atunci:**

**Inca un pas la reteta: mecanismul Higgs**

**Inca un ingredient fundamental: campul Higgs format din bosoni Higgs**

# Campul scalar Higgs

**Peste tot in univers exista un … numar**

**Un camp scalar …**

**… cunoscut de catre public ca si campul Higgs,**

**… dar corect trebuie numit**

**campul Englert–Brout–Higgs–Guralnik–Hagen–Kibble**

**Particulele elementare simt o frecare (vascozitate) cu acest camp Higgs chiar si in vid, astfel incetinesc de la viteza luminii. Astfel, ele primesc masa!**

# Particula scalara: bosonul Higgs

**In stiinta, experimentul == judecatorul unei teorii**

**Trebuie confirmari experimentale pentru TOATE predictiile acestei teorii**

**Dar aceasta teorie are o SINGURA predictie …**

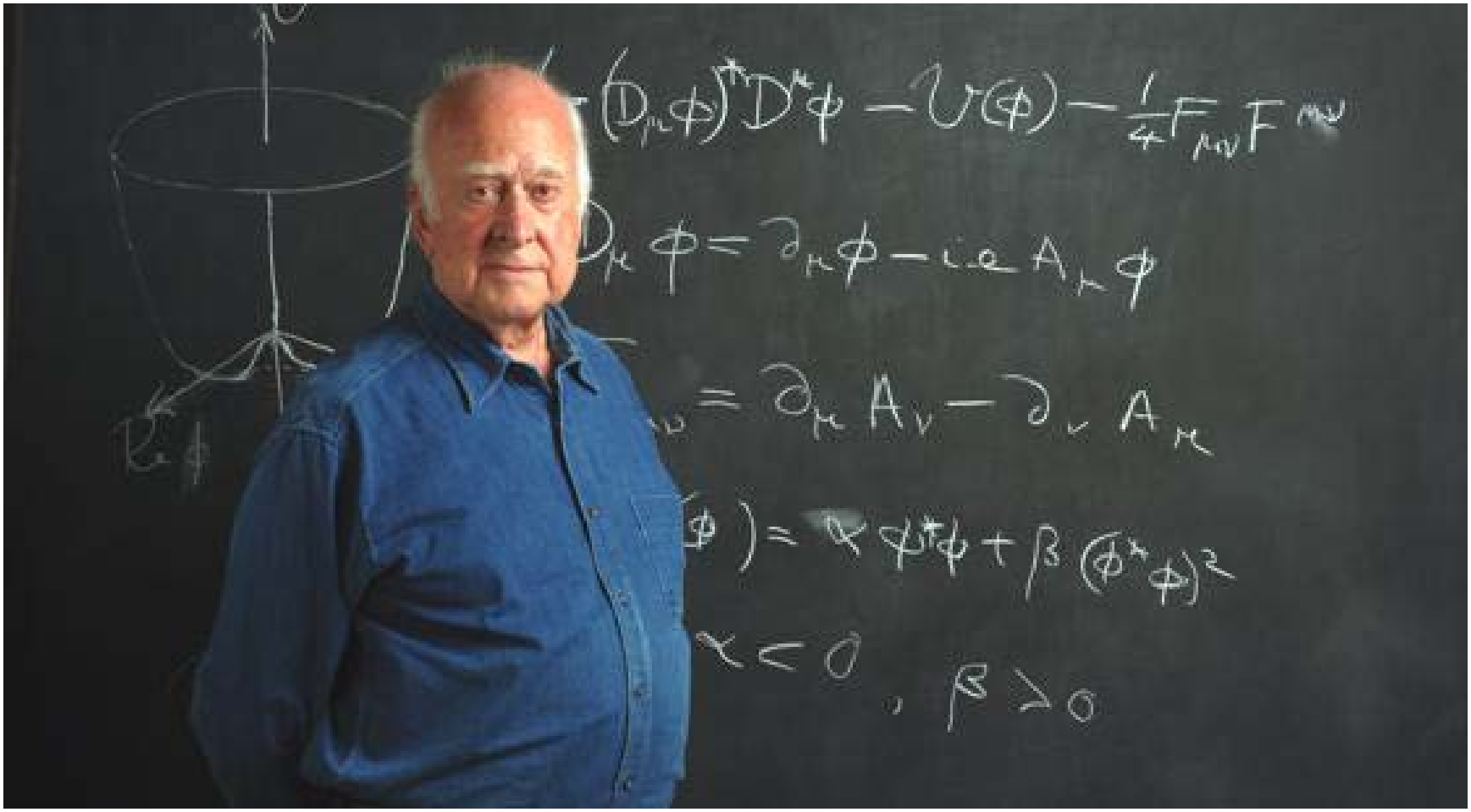
**… existenta unei noi particule elementare …**

**scalara, numerele cuantice zero (ca vidul), probabilitatea de interactie fixata atunci cand masa sa este fixata …**

**Dar masa particulei nu este fixata de teorie!**

**Este tocmai bosonul Higgs!**

# Peter Higgs


$(D_\mu\phi)^* D^\mu\phi - V(\phi) - \frac{1}{4}F_{\mu\nu}F^{\mu\nu}$
$D_\mu\phi = \partial_\mu\phi - ieA_\mu\phi$
$= \partial_\mu A_\nu - \partial_\nu A_\mu$
$\phi) = \alpha\phi^*\phi + \beta(\phi^*\phi)^2$
$\alpha < 0, \beta > 0$

# Analogia cu padurea

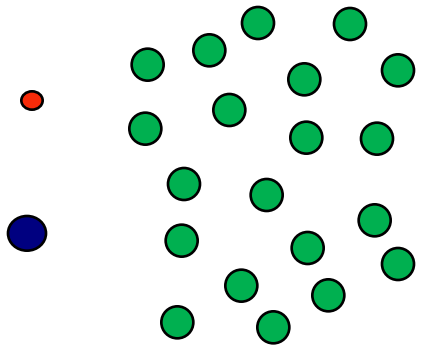
**Aceeasi energie**

**Padure**
**Ciocnire de copaci**

**Cine strabate padurea primul?**

**Unul slabut**

**Unul grasut**



**Cel mai slabut ajunge primul. A fost incetinit mai putin, caci s-a ciocnit cu mai putini copaci.**

**Padurea: campul scalar Higgs**
**Un singur copac: o particula scalara (bosonul Higgs)**
**Ciocniri cu bosonii Higgs => frecare cu campul scalar Higgs => viteza scade fata de viteza luminii => particula primeste masa diferita de zero**

# Teorie si experiment

**Predictie teoretica**
Cine : Urbain Le Verrier
Ce : prezice planeta Neptun
Unde : Franta
Cand : August 1846
Cum : mate/teorie
Pt ce : ciudata orbita a lui Uranus

**Verificare experimentala**
Cine : Johann Gottfried Galle
Ce : a discoperit-o!
Unde : Germania
Cand : Septembrie 1846
Cum : telescop/experiment
Pt ce : experimentul = judecator!

**1 zi doar: telescopul sau era suficient de precis!**

**Predictie teoretica**
Cine : Peter Higgs + ceilalti
Ce : prezice noua particula
Unde : Scotia
Cand : 1964 (acum 49 de ani!)
Cum : mate/teorie
Pt ce : particulele primesc masa

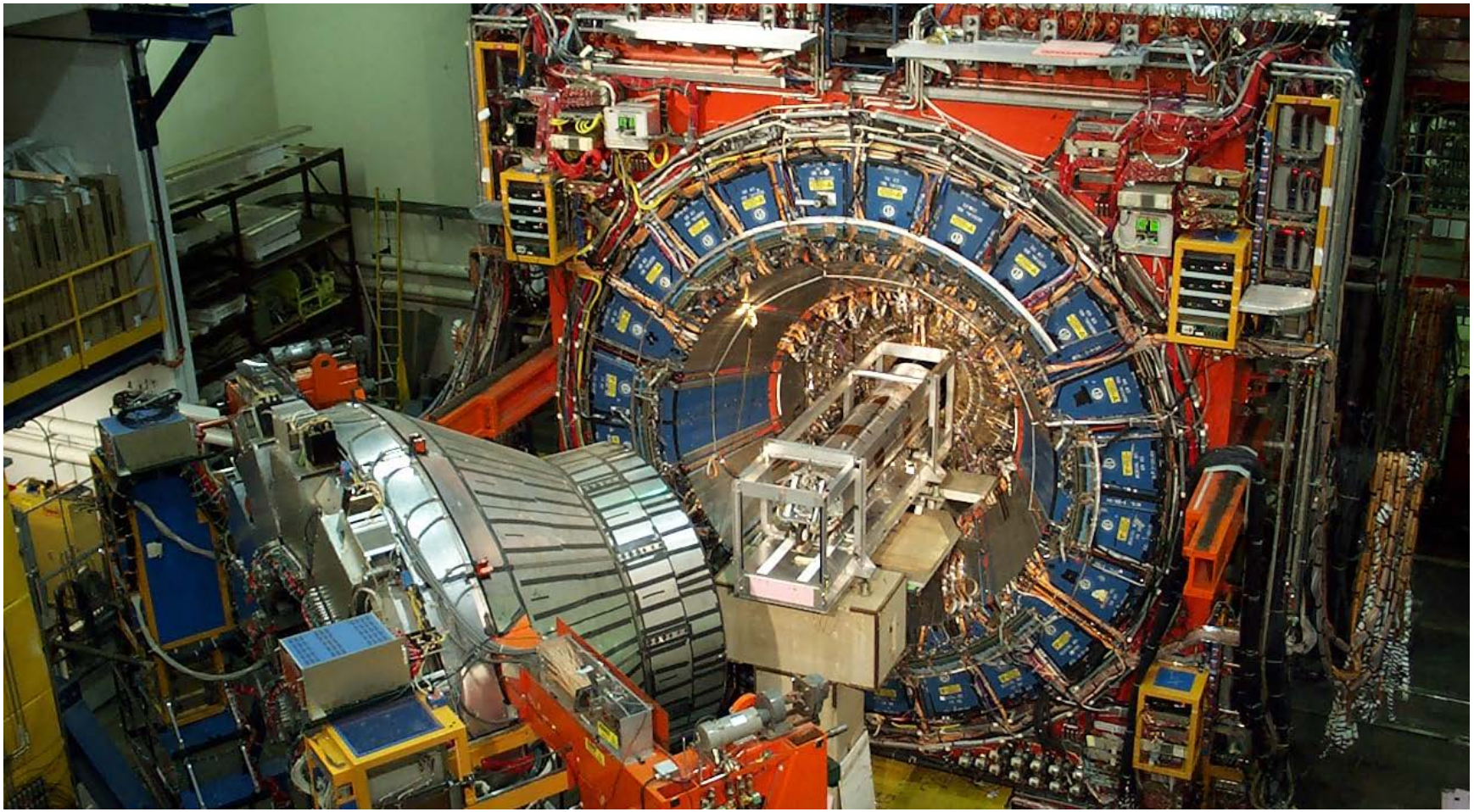
**Aici contribuim noi**

**Verificare experimentala**
Cine : laboratoarele CERN
Ce : a discoperit-o!
Unde : Elvetia
Cand : 2012-2013
Cum : accelerator/detector/experiment
Pt ce : experimentul = judecator!

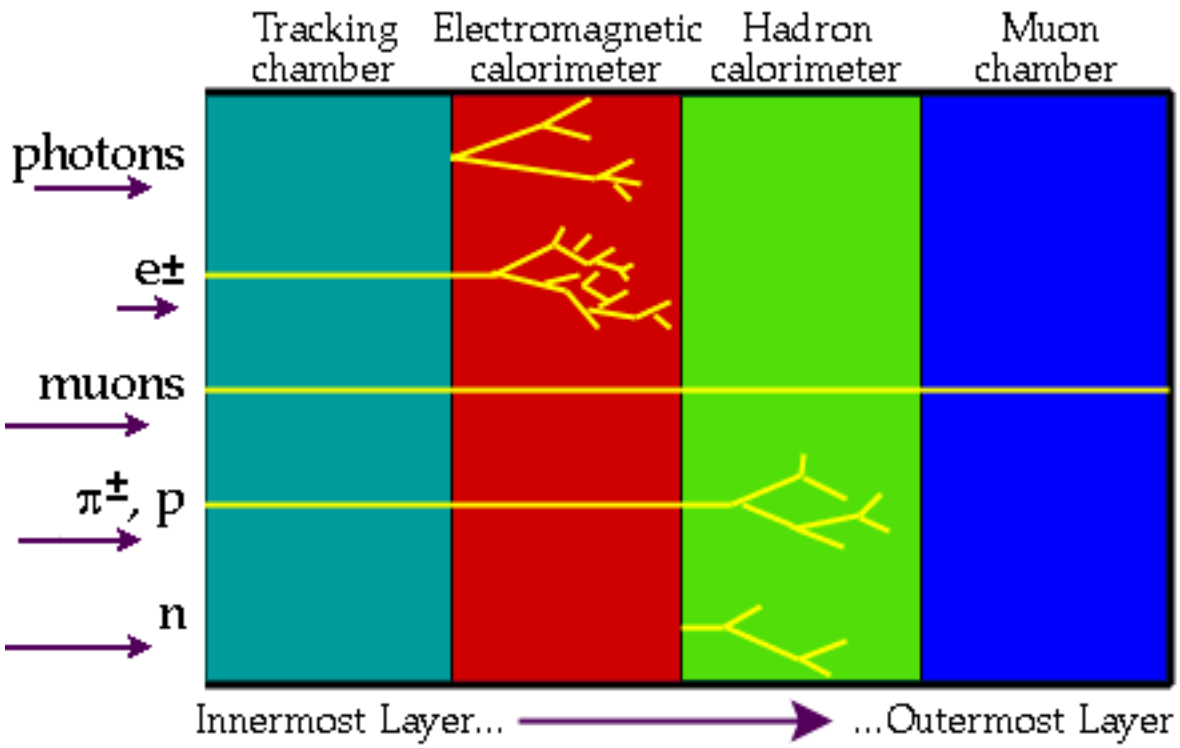
**49 de ani: ne imbunatateam mereu "microscopul"**

# Fermilab, langa Chicago, SUA

# Collider Detector at Fermilab



# Particulele interactioneaza diferit



# Masa bosonului Higgs - Iulie 2011

**Cu 95% incredere, masa sa poate fi doar in intervalul 114.4 - 149 GeV/$c^2$,**

**adica 123 – 160 unitati atomice de masa**

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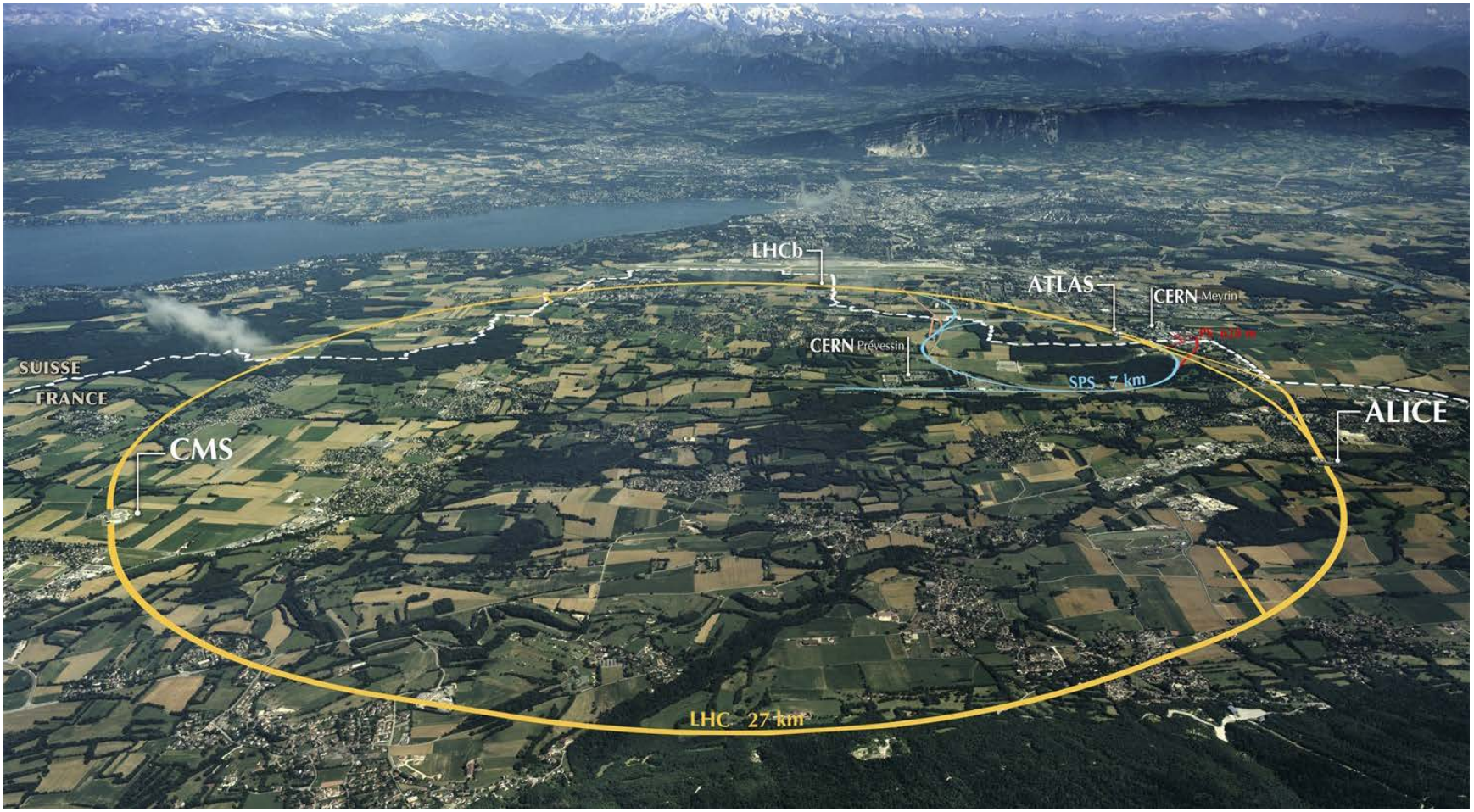
# CERN, Geneva, Elvetia



# ATLAS detector

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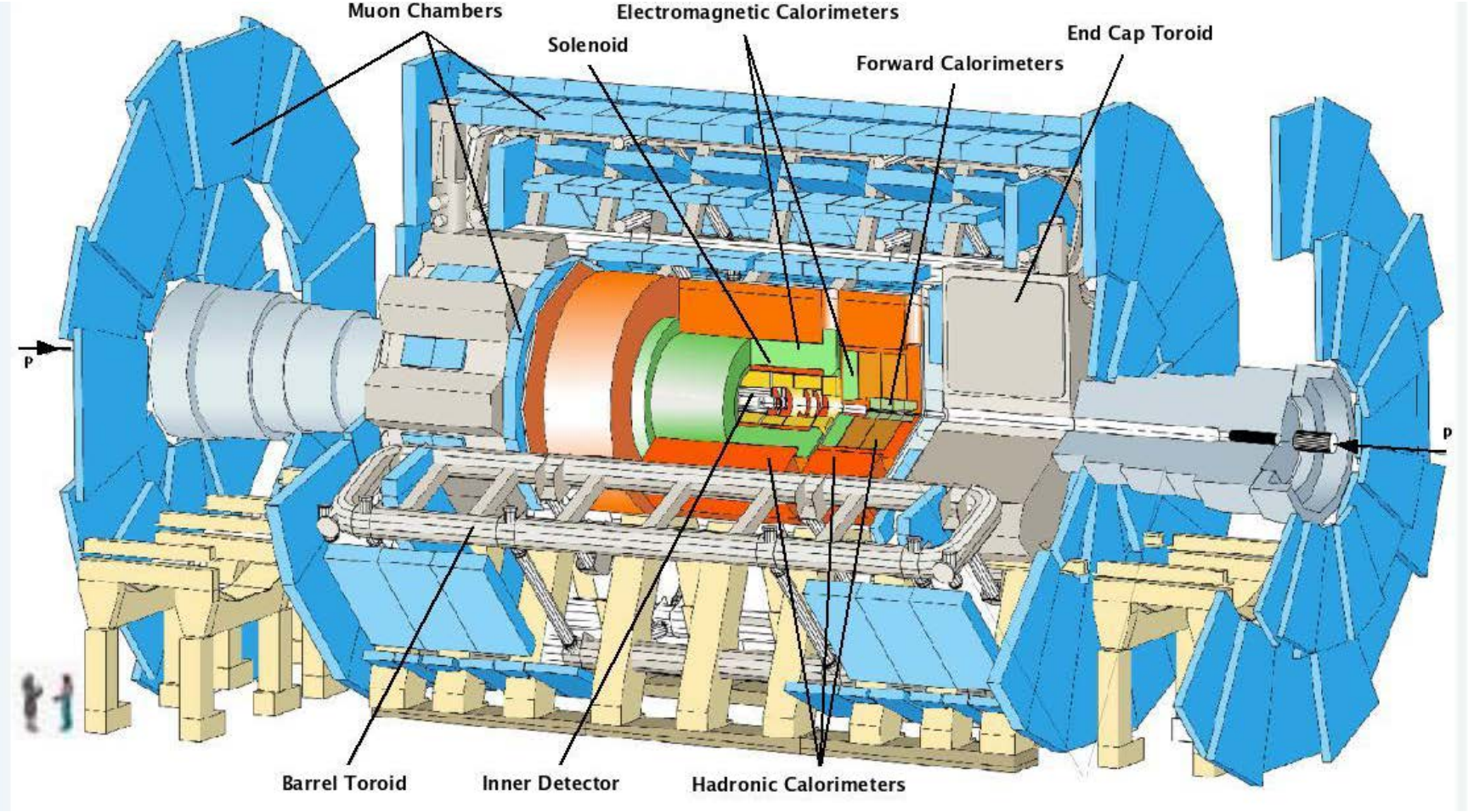

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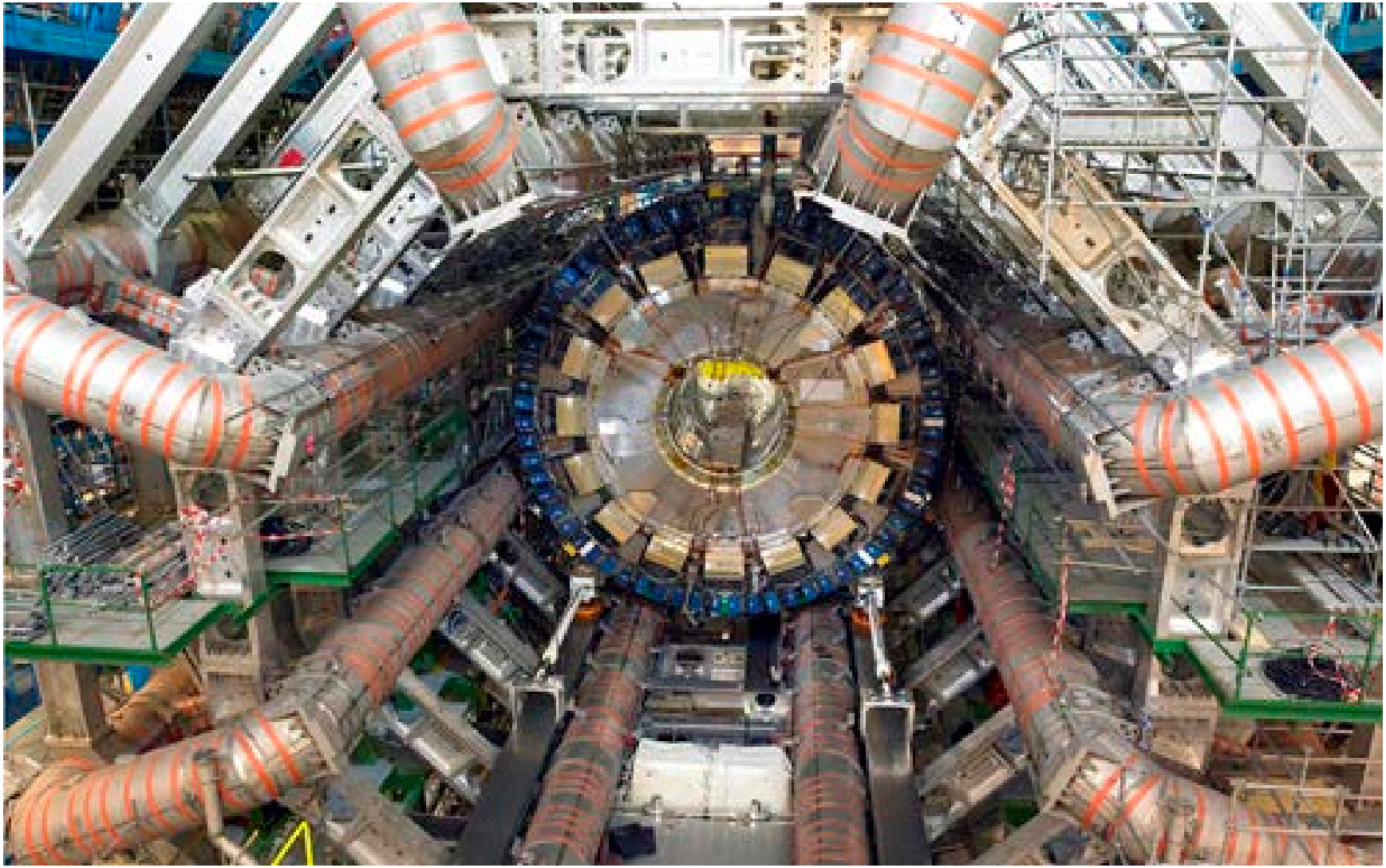

# Masa bosonului Higgs - Martie 2012

**Cu 95% incredere, masa sa poate fi doar in intervalul 115.5 - 127 GeV/$c^2$,**

**adica 124 – 136 unitati atomice de masa**

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# Masa bosonului Higgs – 04 Iulie 2012

**O noua particula elementara “ca un boson Higgs” (in acord cu bosonul Higgs din Modelul Standard) a fost observata in intervalul de mase 125 – 127 GeV/$c^2$, adica 135 – 136 unitati atomice de masa**

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| 55 Cs Cesium 132.9054519 | 56 Ba Barium 137.327 | 57–71 Lantha-nides | 72 Hf Hafnium 178.49 | 73 Ta Tantalum 180.94788 | 74 W Tungsten 183.84 | 75 Re Rhenium 186.207 | 76 Os Osmium 190.23 | 77 Ir Iridium 192.217 | 78 Pt Platinum 195.084 | 79 Au Gold 196.966569 | 80 Hg Mercury 200.59 | 81 Tl Thallium 204.3833 | 82 Pb Lead 207.2 | 83 Bi Bismuth 208.98040 | 84 Po Polonium (208.98243) | 85 At Astatine (209.98715) | 86 Rn Radon (222.01758) |
| 87 Fr Francium (223.01974) | 88 Ra Radium (226.02541) | 89–103 Actinides | 104 Rf Rutherford (267.122) | 105 Db Dubnium (268.125) | 106 Sg Seaborg. (271.133) | 107 Bh Bohrium (270.134) | 108 Hs Hassium (269.134) | 109 Mt Meitner. (276.151) | 110 Ds Darmstadt. (281.162) | 111 Rg Roentgen. (280.164) | 112 (285.174) | | | | | | |

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Lanthanide series | 57 La Lanthan. 138.90547 | 58 Ce Cerium 140.116 | 59 Pr Praseodym. 140.90765 | 60 Nd Neodym. 144.242 | 61 Pm Prometh. (144.91275) | 62 Sm Samarium 150.36 | 63 Eu Europium 151.964 | 64 Gd Gadolin. 157.25 | 65 Tb Terbium 158.92535 | 66 Dy Dyspros. 162.500 | 67 Ho Holmium 164.93032 | 68 Er Erbium 167.259 | 69 Tm Thulium 168.93421 | 70 Yb Ytterbium 173.054 | 71 Lu Lutetium 174.9668 |
| Actinide series | 89 Ac Actinium (227.02775) | 90 Th Thorium 232.03806 | 91 Pa Protactin. 231.03588 | 92 U Uranium 238.02891 | 93 Np Neptunium (237.04817) | 94 Pu Plutonium (244.06420) | 95 Am Americ. (243.06138) | 96 Cm Curium (247.07035) | 97 Bk Berkelium (247.07031) | 98 Cf Californ. (251.07959) | 99 Es Einstein. (252.0830) | 100 Fm Fermium (257.09510) | 101 Md Mendelev. (258.09843) | 102 No Nobelium (259.1010) | 103 Lr Lawrenc. (262.110) |

# Descoperirea noii particule

# Masa particulelor elementare

## Leptoni Cuarci Purtatori de forta

## Unele masive cat atomi masivi!

PERIODIC TABLE OF THE ELEMENTS

| 1 IA | 2 IIA | 3 IIIB | 4 IVB | 5 VB | 6 VIB | 7 VIIB | 8 VIII | 9 VIII | 10 VIII | 11 IB | 12 IIB | 13 IIIA | 14 IVA | 15 VA | 16 VIA | 17 VIIA | 18 VIIIA |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 H Hydrogen 1.00794 | | | | | | | | | | | | | | | | | 2 He Helium 4.002602 |
| 3 Li Lithium 6.941 | 4 Be Beryllium 9.012182 | | | | | | | | | | | 5 B Boron 10.811 | 6 C Carbon 12.0107 | 7 N Nitrogen 14.0067 | 8 O Oxygen 15.9994 | 9 F Fluorine 18.9984032 | 10 Ne Neon 20.1797 |
| 11 Na Sodium 22.98976928 | 12 Mg Magnesium 24.3050 | | | | | | | | | | | 13 Al Aluminum 26.9815386 | 14 Si Silicon 28.0855 | 15 P Phosph. 30.973762 | 16 S Sulfur 32.065 | 17 Cl Chlorine 35.453 | 18 Ar Argon 39.948 |
| 19 K Potassium 39.0983 | 20 Ca Calcium 40.078 | 21 Sc Scandium 44.955912 | 22 Ti Titanium 47.867 | 23 V Vanadium 50.9415 | 24 Cr Chromium 51.9961 | 25 Mn Manganese 54.938045 | 26 Fe Iron 55.845 | 27 Co Cobalt 58.933195 | 28 Ni Nickel 58.6934 | 29 Cu Copper 63.546 | 30 Zn Zinc 65.38 | 31 Ga Gallium 69.723 | 32 Ge German. 72.64 | 33 As Arsenic 74.92160 | 34 Se Selenium 78.96 | 35 Br Bromine 79.904 | 36 Kr Krypton 83.798 |
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# 04 Iulie 2012 – ca un boson Higgs

**Toate proprietatile masurate sunt in acord cu cele ale bosonului Higgs**

**Dar mai erau doua proprietati de masurat (spinul si si paritatea), plus cat de des este produsa particula**

**Bosonul Higgs are spinul zero si paritate pozitiva**

**Odata stiuta masa, in Modelul Standard se prezice exact cat de des este produsa particula**

# Fabiola Gianotti, liderul ATLAS

# 14 Martie 2013 – un boson Higgs

**Cele doua noi proprietati au fost masurate si coincid cu cele ale teoriei**

**Avem asadar “un boson Higgs”**

**De ce nu “bosonul Higgs?”**

**Existe teorii noi care prezic mai multi bosoni Higgs**

**Fizicenii spera sa descopere si ceva nou**

# Concluzii

**Introdus notiunile de particule elementare si interactiile dintre ele ca ingredientele si reteta materiei din Univers**

**Descrierea naturii este incompleta fara originea masei particulelor**

**Acum 49 de ani o teorie a fost propusa sa explice asta**

**Era nevoie de o confirmare sau infirmare experimentala**

**De atunci, fizicenii si-au imbunatatit constant “microscopul”**

**4 Iulie 2012: O noua particula elementara, este “ca un boson Higgs”**

**14 Martie 2013: Noi proprietati masurate, este “un boson Higgs”**

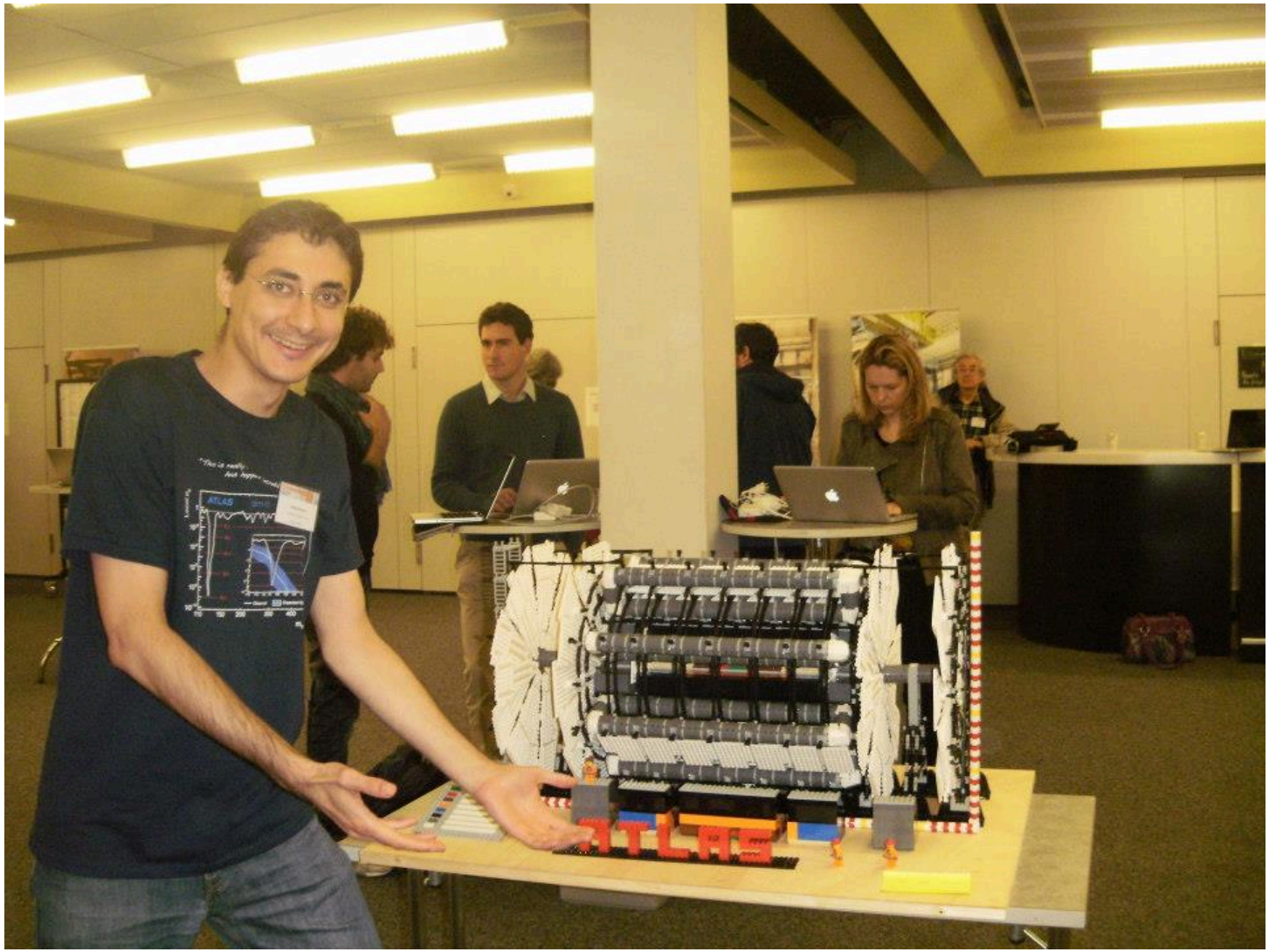
**10 D□ecembrie 2013: Peter Higgs va lua Premiul Nobel?**

**2015-2016: doar unul sau mai multi bosoni Higgs?**

# Adrian Buzatu si Peter Higgs

# Adrian Buzatu

# Adrian Buzatu



# Multumesc!

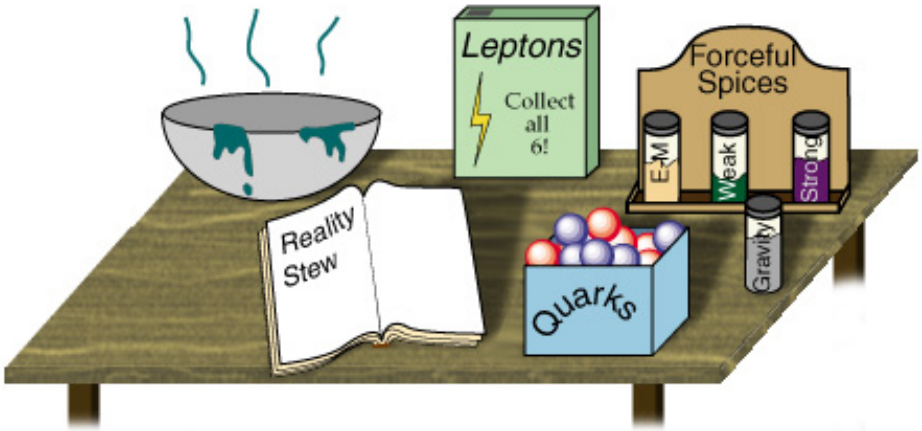
## Intrebari? Sugestii?

## http://adrianbuzatu.ro

**adrian.buzatu@glasgow.ac.uk**


"Quarks. Neutrinos. Mesons. All those damn particles you can't see. That's what drove me to drink. But now I can see them!"

# The Recipe for the Universe




## The Standard Model

- The Universe
  - Ingredients (Elementary Particles)
    - Quarks
    - Electrons
    - Other elementary particles
  - Recipe (Interactions)
    - Electromagnetic — Light, radio, radar
    - Strong — Nuclear stability
    - Weak — Radioactivity
    - Gravitational

# The Scientists' Room Analogy

Celebrity crossing the room → Then s/he attracts people → S/he slows down, has inertia → As if s/he acquires mass

Normal Particle

A rumour comes into the room → It still attracts people → A group is formed and has inertia → As if group acquires mass

Higgs Particle

# The Tevatron Accelerator

**Fermilab, near Chicago, USA**

**Complex of particle accelerators**

**Collides matter and antimatter**

**(protons and antiprotons)**

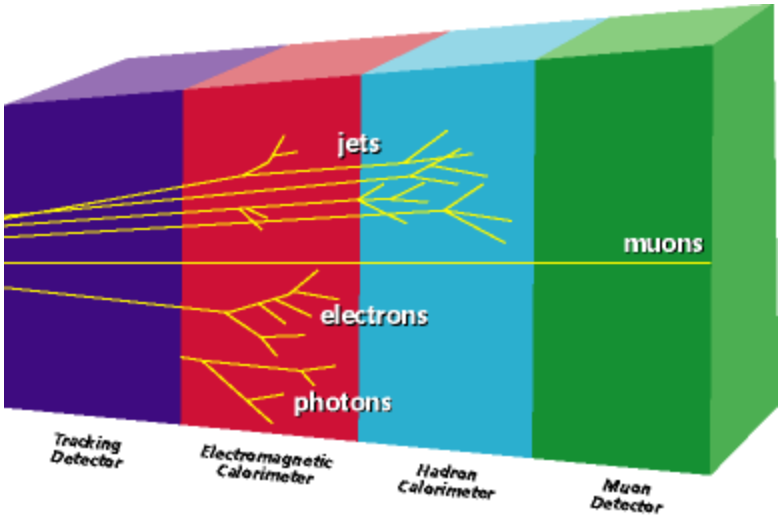
**150 m/s less than the speed of light**

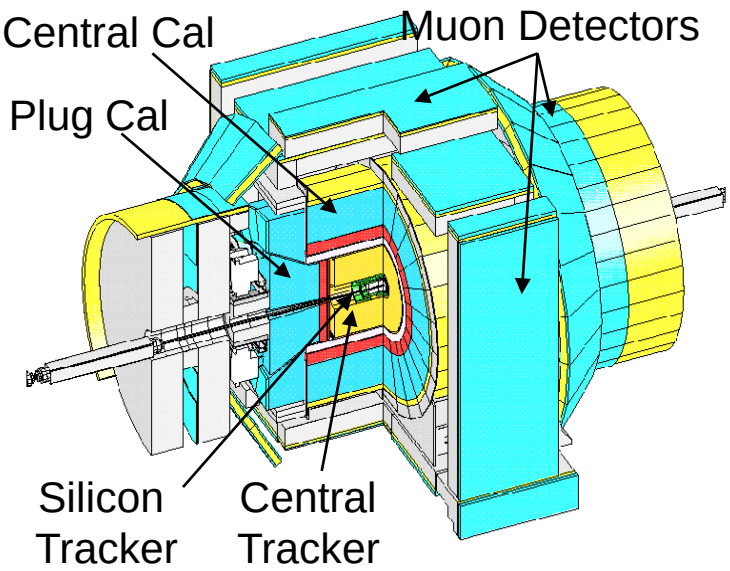
**(300 million m/s)**

**2.5 million collisions per second**

**2 collision locations: CDF and DZero**

# Collider Detector at Fermilab



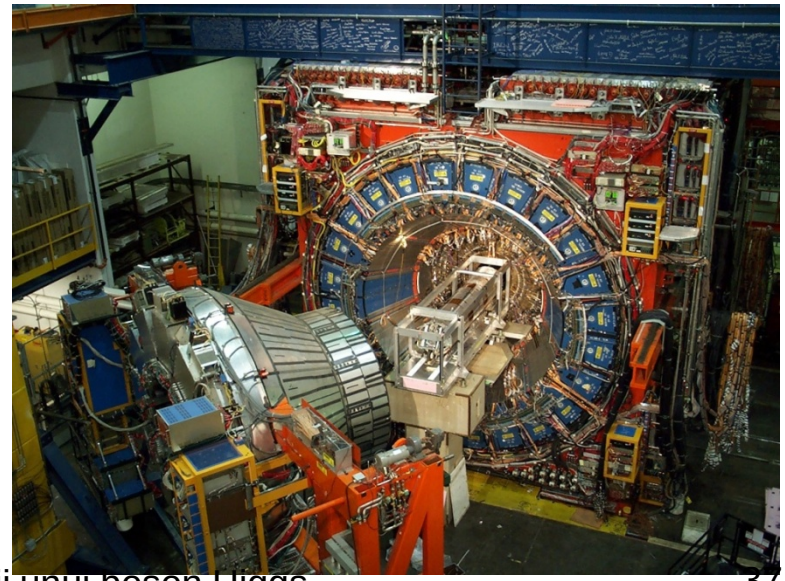




**A particle detector (3D digital camera)**

**As big as a huge room**

**Layers of subdetectors**

**Measuring particle type, direction of movement, energy and momentum**

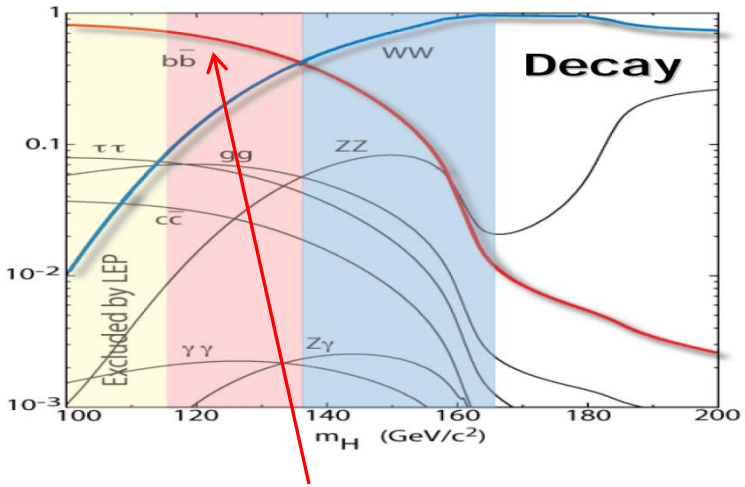


# The WH Associated Production

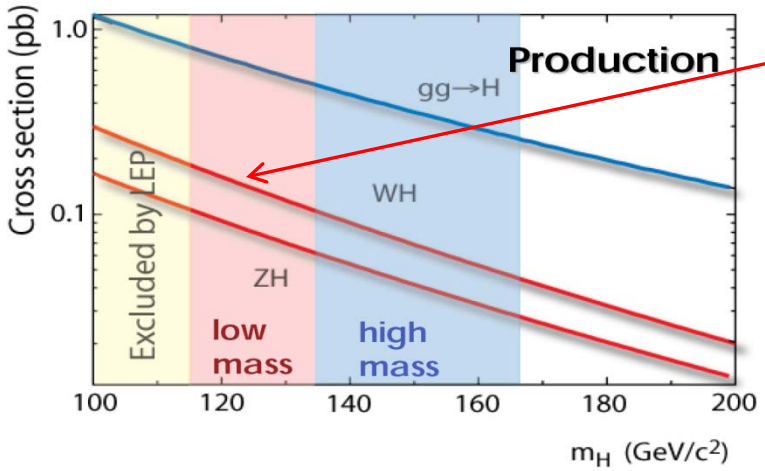
**Our search: a W boson + a Higgs boson**

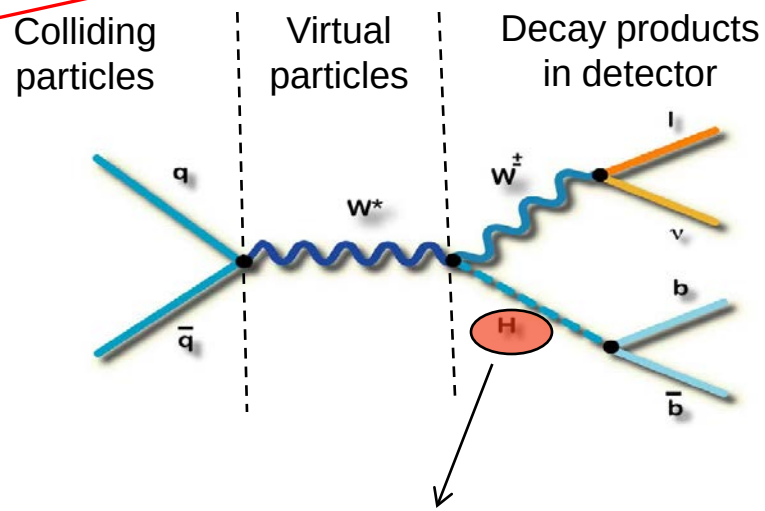
**The W boson decays to an electron (muon) + neutrino**

**It helps us a lot that we can indentify well electrons and muons in the detector**




**Our search (WH)**




Higgs Particle (H)
Elementary particle as massive as heavy atoms

# My Improvement

**Charged lepton (Electron or Muon)**

**My contribution to improve the search:**

**More charged leptons, which means**

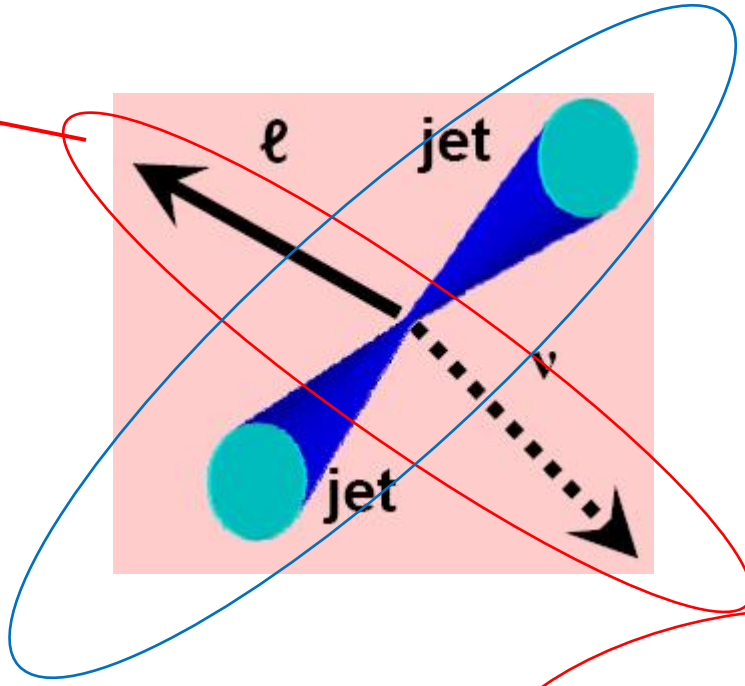
**More W bosons, which means**

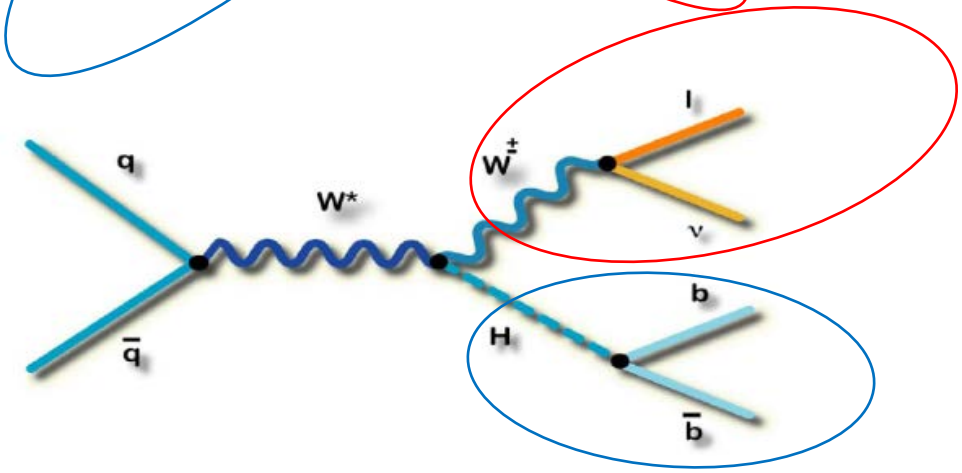
**More WH events, which means**

**More signal selected, which means**

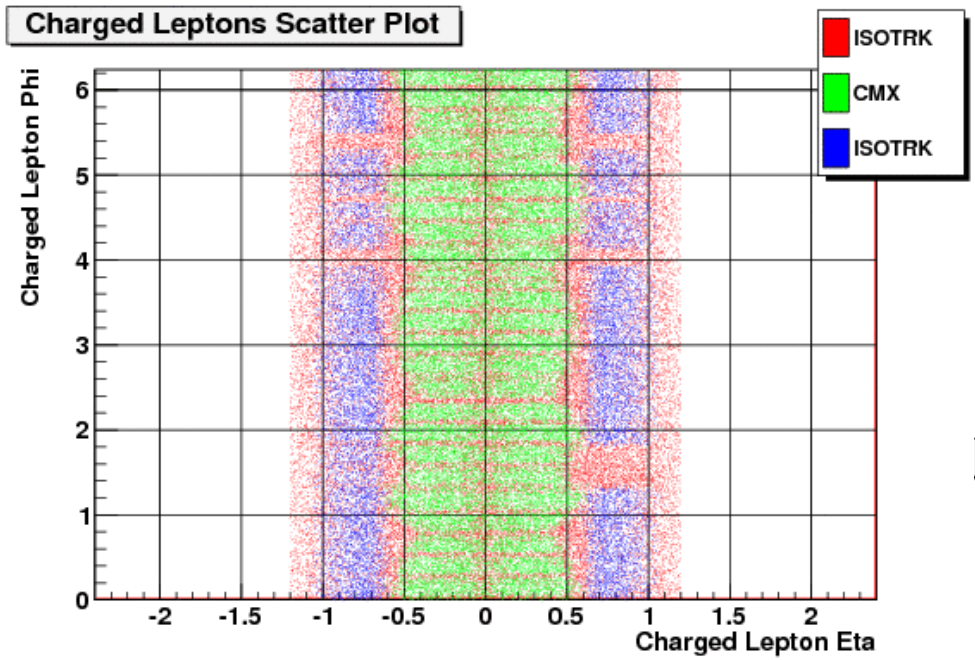
**More precise "microscope"!**

**We introduce a new method to reconstruct electrons and muons that would normally be lost in the non instrumented regions of the detector**



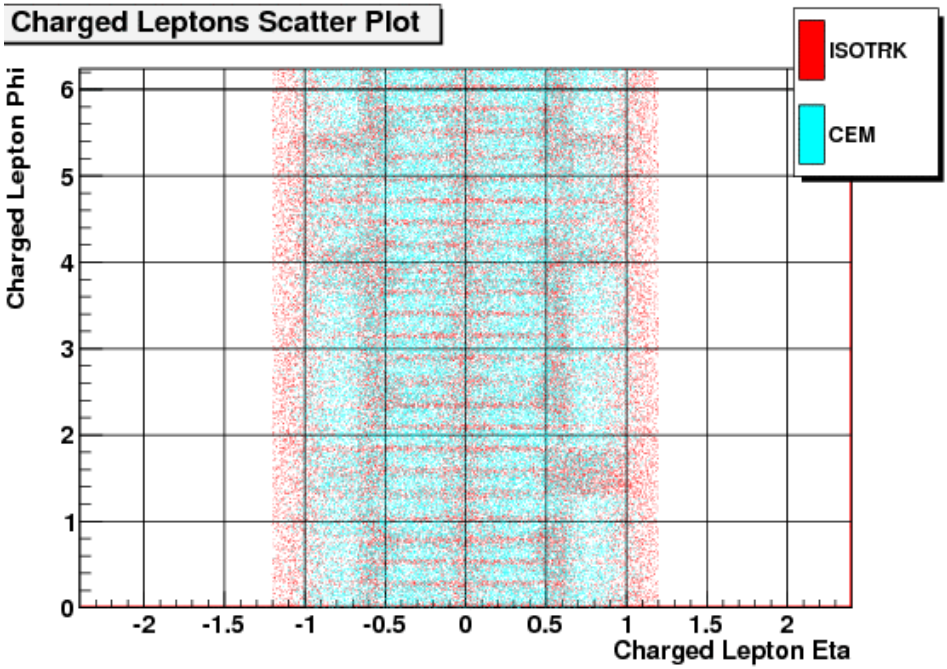



# Charged Lepton Improvement



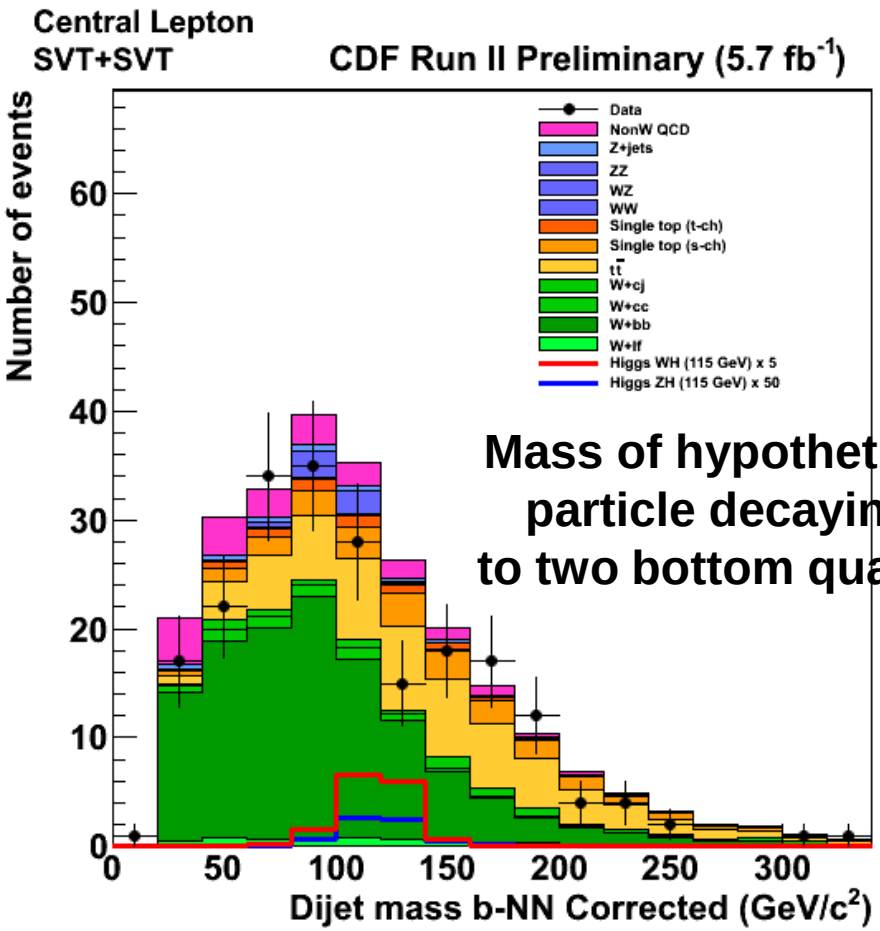

Cylindrical detector rolled on a plane

Y axis: 0-2Pi
X axis – 0 for half height

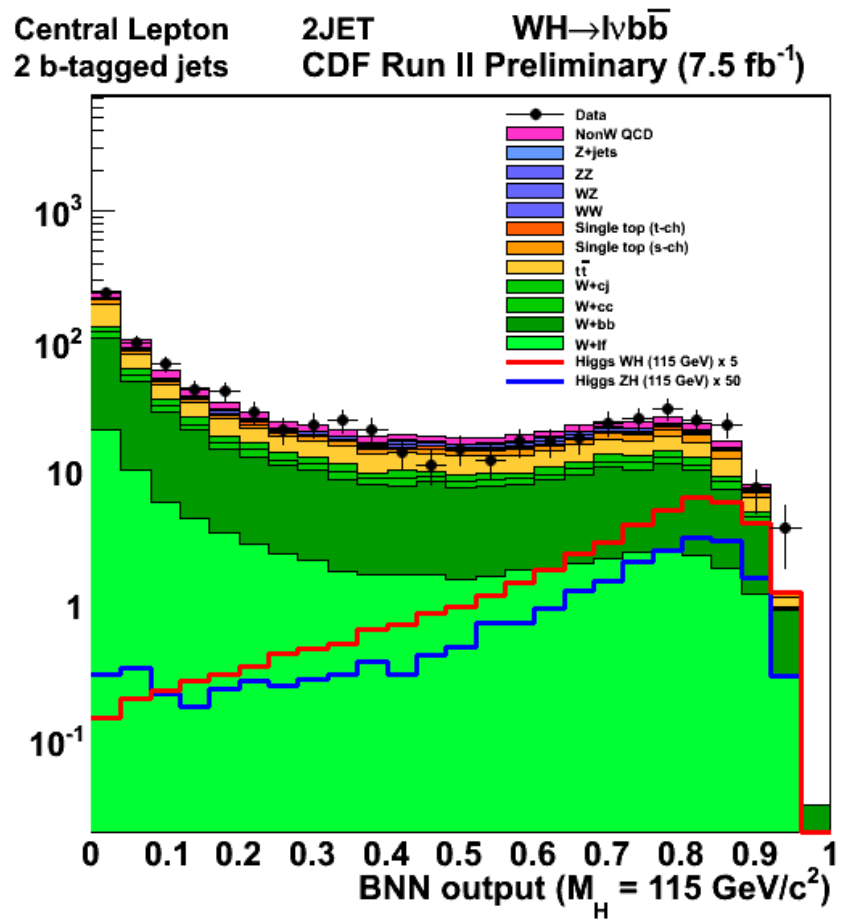



**Dark blue, Green – muons**
**Light blue – electrons**
**Red – muons or electrons that would be lost in the non instrumented regions of the detector, but we recover**

# Key Analyses Variables



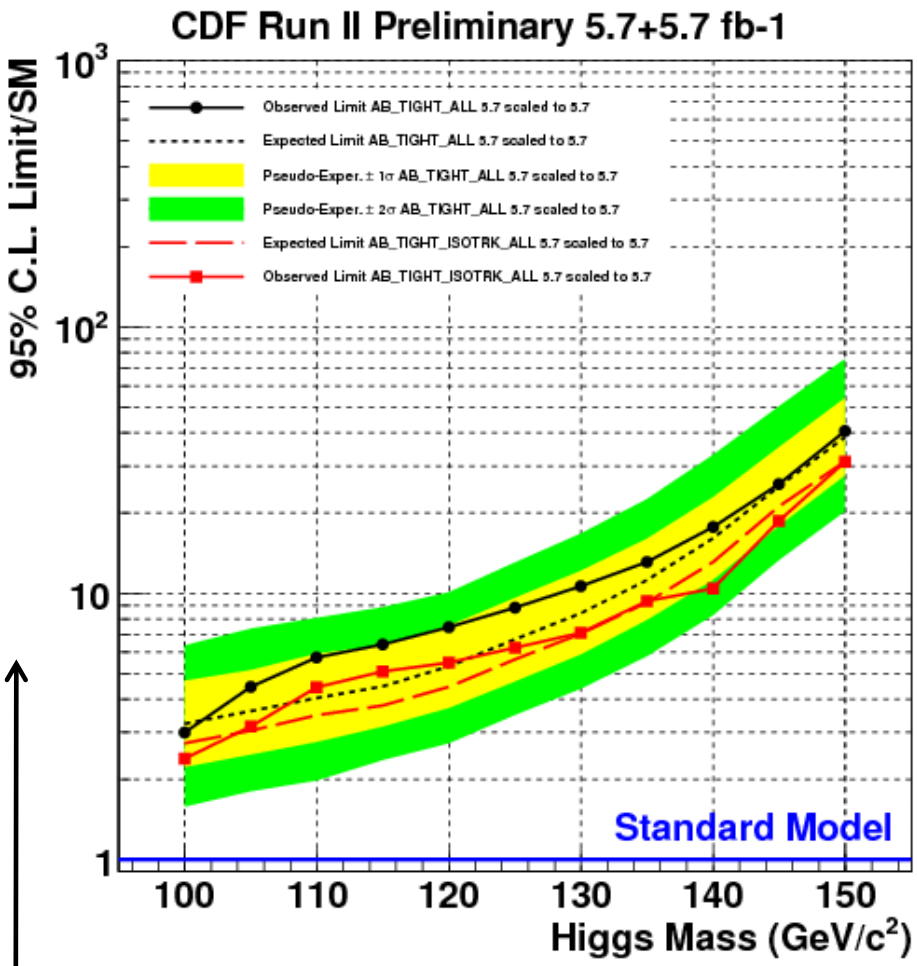

**Mass of hypothetical particle decaying to two bottom quarks**




**Output of trained artificial neural network with background peaking at 0 and signal at 1**

**Red: WH Signal multiplied by 5 times!**

# My PhD Result – 3 August 2011




**Y axis: Measurement divided by theory prediction**

**Dotted line: how precise our "microscope" is**

**Solid line: what we actually measure with our "microscope"**

**Name of the game: drive the solid line below 1 to exclude the Higgs boson!**

**Black: the WH analysis before my contribution**

**Red: with the addition of my original PhD contribution, the WH analysis improves both the precision of the "microscope" and the actual measurement**